

# STUDIES IN REMOTELY SENSED GEOPHYSICAL PARAMETER RETRIEVAL AND ANALYSIS

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THE GEORGE C. MARSHALL SPACE FLIGHT CENTER

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## FINAL PROGRESS REPORT

### STUDIES IN REMOTELY SENSED GEOPHYSICAL PARAMETER RETRIEVAL AND ANALYSIS

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#### Visiting Scientists and Research Associates

Dr. Bill McCaul served as an Associate Scientist, and Mr. Grant Carlson and Mr. Frank LaFontaine served as Research Associate II's on this project during their appointment. Mr. Dennis Buechler served as a Visiting Scientist through October 25, 1991. During his appointment he performed research on the effect of the environment on lightning and rainfall relationships.

#### 1. Activities Performed

Dr. Eugene W. McCaul has accomplished a number of research tasks during the period of this contract. He developed software to read, display, and manipulate data from the NASA DC8's Data Acquisition and Display System (DADS), lidar data from the various GLOBE principal investigators, and global scale meteorological data from the European Centre for Medium-Range Weather Forecasts (ECMWF). These data have been examined using a variety of graphical tools, most recently LinkWinds as implemented on a Silicon Graphics workstation. The ECMWF data have been converted from their three dimensional form into two-dimensional curtains collocated in space and time with the lidar data taken during the GLOBE flights. All data have been archived in standard HDF format.

Statistical studies were conducted on the collocated lidar and ECMWF data to see if there is a diagnostic relationship between the lidar backscatter and any meteorological variable. Results indicate that only the moisture variables, with their maxima in the boundary layer and upper troposphere, show significant correlations with the lidar backscatter.

Because of the intermittent character of the lidar data fields, Dr. McCaul assessed the significance of the backscatter-moisture correlations using a Monte Carlo technique in which the ECMWF humidity fields were randomized using a Fourier technique that preserves the original spectral content of the moisture field, but redistributes it spatially. These tests suggest that there is only a 4-6% chance of randomly obtaining correlations as high as those actually observed. However, the correlations, while significant, are only around 0.5, apparently because of occasional high backscatter events in dust plumes, where the correlation with moisture is reversed.

Dr. McCaul worked with investigators to devise improved lidar data editing and analysis techniques, in order to clear up some discrepancies detected during data visualization. Once optimum quality datasets are obtained, statistical analyses will be rerun and formal manuscripts will be prepared for publication.

Dr. Grant Carlson's activities under this research have consisted of the development and application of parameter retrieval algorithms and radiative transfer models, directed toward establishing improved methods of detecting the variability of atmospheric constituents at small horizontal scales. He worked in close cooperation with Dr. Gary J. Jedlovec (NASA/ES43) and other scientists in the Earth System Observing Branch, as a member of the Infrared Measurements

and Modeling Group. During this period, he provided scientific and programming support for many ongoing research efforts within the group, while focusing his initiatives in the areas of ozone and water vapor retrieval technologies, and on methods of developing simulated data for remote sensing systems. He performed considerable software development incorporating advanced radiation models to produce synthetic imagery for numerous aircraft and satellite based instruments. These simulated data sets, developed from high resolution forecast model surrogate atmospheres, have been very useful in determining the ability of various sensors to discriminate features in the atmosphere of meteorological significance. He also used them extensively to understand the effects of changes in the parameter retrieval methodology. His most important contribution has been in the area of retrieval algorithm development. He used and adapted several existing methods, and applied them to various case studies. His most valued contribution was the creation of MatRet, a very flexible iterated multiple channel matrix inversion algorithm for simultaneous retrieval of water vapor, ozone, and skin temperature. It is physically based, and requires only a single guess profile representative of regional atmospheric conditions. It has been applied to Visible Infrared Spin-Scan Radiometer (VISSR) Atmospheric Sounder (VAS), Multispectral Atmospheric Mapping Sensor (MAMS), Thermal Infrared Multispectral Scanner (TIMS) and Wildfire data for several case studies, as well as to simulated data we developed for the GOES-I Imager and Sounder instruments. It has performed well and has recently been distributed to Florida State University (FSU) to support their GOES I-M Evaluation water vapor research, and for independent performance comparisons with existing well known moisture retrieval algorithms.

Dr. Carlson played a key role in MSFC's planning for and participation in the STormscale Operational and Research Meteorology (STORM) Fronts Experiment Systems Test (STORM-FEST) experiment. He performed many simulation studies to determine the optimum Wildfire instrument channel configuration for ozone retrieval, and also to evaluate the feasibility of flying the TIMS instrument should the Wildfire become unavailable. He included this work, and a discussion of the ozone retrieval methods, in the presentation entitled, "Remote Sensing of Ozone Variability Using an Airborne Scanning Infrared Spectrometer," which was presented at the Fifth Topical Meeting for Optical Remote Sensing of the Atmosphere, November 18-21, 1991, in Williamsburg, Virginia.

During the STORM-FEST ER-2 deployment Dr. Carlson served as the Instrument Principal Investigator for Wildfire for eight days in Houston. Following the experiment, the task of assessing and documenting the data collected during the eleven flights was undertaken. As a result of this, he co-authored NASA Technical Memorandum (TM)-108393 with Dr. Jedlovec entitled, "Wildfire and MAMS data from STORM-FEST." During this task he discovered unexpected channel-to-channel relationships in the Wildfire data, and have devoted a great deal of effort in diagnosing probable causes, and in exploring suitable correction solutions. Simulation studies and extensive data intercomparisons with contemporaneous High-resolution Interferometer Spectrometer (HIS) data also collected from the ER-2 during STORM-FEST have suggested that an undesired shift in the spectral positions of the ozone sensing bands had occurred. Unfortunately, residual uncertainties in the calibration coefficients have cast doubt on the reliability of ozone retrievals made and thereby compromised some of the scientific objectives for STORM-FEST. But because the MODerate-resolution Imaging Spectrometer (MODIS)

Airborne Simulator (MAS) instrument and the MODIS being planned for Earth Observing System (EOS) share many of Wildfire's design features, it is important that steps be taken in the future so that accurate calibration coefficients representative of actual in-flight performance can be developed for these instruments. Dr. Jedlovec and Dr. Carlson have documented their investigations into this matter in a NASA TM entitled, "Intercomparison of Wildfire and HIS data from STORM-FEST: An Investigation of Wildfire Spectral Channel Discrepancies."

The Geostationary Operational Environmental Satellite (GOES)-Next Evaluation activities have been steadily increasing, and continue to be coordinated with FSU. Synthetic multi-channel GOES-I imagery datasets have been prepared for a selected case study, and various simulated GOES water vapor retrieval analyses using our MatRet package have also been prepared. Arrangements have been made to exchange simulated GOES-I imagery and derived retrieval products with the University of Wisconsin, for comparison of results from independent methods. A firm understanding is anticipated of the GOES-I water vapor detection capabilities established prior to the planned launch of the instrument in April, 1994.

Mr. Frank J. LaFontaine's main emphasis was in software development, data analyses, and scientific support. He worked with Ms. Robbie Hood and Dr. Roy Spencer of NASA/MSFC and was Co-author of the Advanced Microwave Precipitation Radiometer (AMPR) Quick View System (QVS). The AMPR flies on-board the NASA ER-2 aircraft, and is a passive microwave radiometer designed to detect emissions at 10.7, 19.35, 37.1, and 85.5 GHz. He developed and used many graphical packages.

He participated in four field experiments: the Convection and Precipitation Experiment (CaPE) (7/91 - 8/91), the STORM I - Fronts Experiments Systems Test (STORM-FEST) (1/92 - 2/92), the Tropical Ocean Global Atmosphere Coupled Ocean-Atmosphere Response Experiment (TOGA COARE) (1/93 - 2/93), and the Convection and Atmosphere Moisture Experiment (CAMEX) (9/93 - 10/93). Tasks included assisting engineers in solving instrument problems, modifying and developing software for the AMPR QVS, performing data analyses and judging data quality as scientific lead or co-leader, and providing input as to the real-time and short-term forecast weather for help in determining mission status.

Mr. LaFontaine also performed WetNet software development on the IBM 3090, the SGI IRIS 4D/440, and the PC in the OS2 and/or the SGI UNIX environments for use with the University of Wisconsin McIDAS package and other auxiliary software on the Special Sensor Microwave/Imager (SSM/I) listed below:

- --- SSM/I brightness temperature -- global browses
- --- SSM/I geophysical products -- global browses
- --- SSM/I brightness temperature -- full resolution
- --- SSM/I geophysical products -- full resolution

His geophysical products included algorithms from many authors and other sources, such as rain rate, total precipitable water, cloud liquid water, marine wind speed, land classification, land surface temperature, sea ice fraction, sea ice age, precipitation (scattering) index. He built

calibration codicils and lookup directories to acquire knowledge of SSM/I navigation ephemeris and interactions with McIDAS navigation routines.

Mr. LaFontaine's primary function was to provide scientific input to the project as a team member. Other major involvements included scientific analyst and programmer in the Precipitation Intercomparison Project - 1 (PIP-1).

## 2. Publications

McCaul, Eugene W., "A Low-Precipitation Cumulonimbus Along the Dryline in Colorado," Monthly Weather Review, AMS, Vol. 118, No. 12, December 1990.

McCaul, Eugene W., Bowdle, David A., Cutten, Dean R., Menzies, Robert T., and James D. Spinhirne, "Relationships Between Lidar Backscatter and Meteorological Fields," 1991.

McCaul, Eugene W., "Diurnal Variations in Times of Hurricane Landfall in the United States," Preprint Volume of the *19th Conference on Hurricanes and Tropical Meteorology*, May 6-10, 1991. Published by the American Meteorological Society.

Buechler, D. E., and S. J. Goodman, "Radar Characteristics of Cloud-To-Ground Lightning Producing Storms in Florida," Preprints for the *25th International Conference on Radar Meteorology*, June 24-28, 1991, Paris, France.

McCaul, Eugene W., "Buoyancy and Shear Characteristics of Hurricane-Tornado Environments," Monthly Weather Review, AMS, Vol. 119, No. 8, August 1991.

Carlson, Grant S., and Gary J. Jedlovec, "Remote Sensing of Ozone Variability Using An Airborne Scanning Infrared Spectrometer," *Optical Society of America's Conference on Optical Remote Sensing of the Atmosphere*, November 1991.

Spencer, R. W., R. E. Hood, F. J. LaFontaine, and E. A. Smith, "High resolution Imaging of Rain Systems with the Advanced Microwave Precipitation Radiometer," Submitted to Journal of Atmospheric and Oceanic Technology, approved and in publication, 1993.

Turk, J., J. Vivekanandan, F. S. Marzano, R. E. Hood, R. W. Spencer, and F. J. LaFontaine, "Active and Passive Microwave Remote Sensing of Precipitating Radiometer and Polarimetric Radar Measurements and Models," Submitted to Meteorology and Atmospheric Physics, Special Issue on Physical Retrieval of Hydrological Variables from Space-based Microwave Instruments, 1993.

Kniveton, D. R., B. C. Motta, M. Goodman, (Order TBD: E. Barrett, F. J. LaFontaine, M. R. Smith), "The First WetNet Precipitation Intercomparison Project Generation of Results," Remote Sensing Review, Special Edition, in progress, 1993.

S. J. Goodman and F. J. LaFontaine, "The First WetNet Precipitation Intercomparison Project: Intercomparison Results," Remote Sensing Review, Special Edition, in progress, 1993.

### 3. Consultants

The following consultants were retained by USRA to provide services on this project. The consultants and their activities are listed below in alphabetical order.

Dr. William L. Boeck from NASA Marshall Space Flight Center was authorized to travel to Cocoa Beach, Florida, April 16-19, 1991, to attend the International Aerospace and Ground Conference on Lightning and Static Electricity. He was also authorized to travel to Baltimore, Maryland, from May 28-29, 1993, to attend the American Geophysical Union's Spring Meeting.

Dr. Ernest Agee from Purdue University was authorized to travel to Huntsville, Alabama, to give a presentation to the Earth Science and Applications Division at NASA/MSFC, June 6-7, 1991.

Dr. James McGurik from Texas A & M University, was authorized to travel to Santa Barbara, California, February 16-22, 1991, to attend a WET-NET meeting.

Dr. Stephen J. Schiller from South Dakota State University visited NASA/MSFC from June 15, 1991, to September 15, 1991.

Mr. Loren White from NASA/MSFC worked as a consultant from May 19, 1991, through September 1991, to participate in the Summer Visitor Program in the Fluid Dynamics Branch, Earth Science and Applications Division involving climate simulation using a global circulation model and assisting members of the ESAD division concerning collection, display and analysis of data obtained from spaceborne instruments that are of use in climate simulation.

Dr. Donald J. Perkey from Drexel University, Philadelphia, Pennsylvania, was retained as a consultant for the period of March 15, 1993, through August 31, 1993, to interact with USRA scientists regarding progress on their scientific endeavors and with responsible NASA counterparts regarding the status of the work on this contract.

### 4. Subcontracts

USRA entered into a subcontracting relationship with The University of Bristol, United Kingdom from January 1989, through January 1993. Three key personnel, Dr. D. Kniveton, Dr. C. Kidd and Dr. E. C. Barrett. The work was entitled, "Rain and Snow Evaluation and Monitoring by the SSM/I as a Contribution to the WETNET Project." The following tasks were performed in three stages.

- Cold-season testing of the Bristol polarization/frequency algorithm approach to rain-area and rain-rate evaluation, based on SSM/I-2 data.
- Develop and refine a global rainfall algorithm, capable of yielding additional categories of rainfall at the higher rain-rate end of the scale than at present; and apply the result of both instantaneous cases and climate-scale periods.
- Use the SSM/I for snow area monitoring under conditions of heavy and/or continuing cloud cover.

- Examine the possibility of identifying and evaluating falling precipitation over areas of snow and ice.

A Final Report dated January 1993, remains on file at the USRA Corporate Drive Office, in Huntsville, AL.

5. Financial

Total Contract Value:

Total Cumulative Costs:

Estimated Cost to Complete:

Physical Completion of the Statement of Work is consistent with expenditures to date. A no cost extension had been granted for this contract through December 31, 1993, in Supplemental Agreement 10, dated November 30, 1993.



## Report Documentation Page

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16. Abstract  This report describes USRA activities in support of the Geophysical Parameter Retrieval and Analysis studies. Specifically it addresses the following areas: <ul style="list-style-type: none"><li>a) personnel assigned to the effort</li><li>b) travel</li><li>c) consultant participants</li><li>d) technical progress</li><li>e) contract spending</li></ul>					
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